Pest Management Grants Final Report
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Reducing Insecticide Use on Celery Through Low-input Pest Management Strategies

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Acknowledgments:

This report was submitted in fulfillment of DPR contract number 97-0228, “Reducing Insecticide Use on Celery Through Low-input Pest Management Strategies” by the University of California, Riverside, under the partial sponsorship of the California Department of Pesticide Regulation.

Abstract:

We implemented a low-pesticide-input integrated pest management system for celery, and compared its performance with conventional higher-input management systems over two years. Because of low damage thresholds, celery is among the most intensively managed vegetable crops and therefore is a model system for development of low-input IPM programs.

In both years, the low-input program used significantly fewer pesticides than the conventional program, yet had equivalent yields. Because of the lower pesticide use, the low-input system had more favorable net profits. In addition to the favorable economic results, the low-input IPM program had benefits for the environment. All insecticides selected for use in the low-input system are formulated without volatile solvents. Therefore this low-input approach would not contribute substantially to air pollution from volatile emissions.

We have demonstrated that further reductions in pesticide use can be made in the production of high value vegetable crops. This reduction can be made without sacrificing yield, quality or net profit. The progressive pest management policy of the grower made this validation test of the low-input IPM program conservative. Therefore, many growers could show greater economic benefits from adoption of such low-input programs.

Executive Summary:

We proposed to implement a low-pesticide-input integrated pest management (low-input IPM) system for celery, and compare its performance with conventional high-pesticide-input management systems. This project directly relates to the DPR program's goals of making agriculture economically viable, environmentally sound, and socially viable. Because of low damage thresholds, celery is among the most intensively managed vegetable crops and therefore is a model system for development of low-input IPM programs. Successful development of low-input IPM programs in such an intensively managed crop should facilitate the acceptance of similar programs for other vegetable crops.

The two years of this project were conducted on a commercial scale in collaboration with a celery producer, in Ventura County, CA. In the first year, the low-input IPM program used significantly fewer insecticides than the grower standard program. The success of the low-input program encouraged the grower to use a similar approach in the second year. Still, in the second year the low-input IPM used significantly fewer insecticides than did the grower standard without sacrificing yield or net profits. Therefore, over both years we have demonstrated that further reductions in pesticide use can be made by the vegetable industry, thereby reducing costs and improving economic returns for growers. The results of the first year of the study have been accepted for publication in the journal *Agriculture, Environment and Ecosystems.* A copy of the article is included with this final report. This report will therefore focus on the second year of the study.

The low-input IPM program relied on biological control agents, and environmentally safe bio-rational insecticides applied only "as needed" in a rotational strategy to delay pesticide resistance. In the second year of this cooperative research project, the grower adopted many aspects of the low-input program. The insecticides selected for use by the grower were the same as those proposed for use in the low-input IPM program. The need for insecticide applications in the low-input IPM program was determined from weekly insect samples. Hence, the low-input insect management program used 27% fewer insecticides than the grower standard did. Although the low-input program used significantly fewer insecticides than the grower standard, there was no significant difference in yield or net profit between the treatments. The grower standard practice had an average yield of 2,731 marketable cartons per hectare (1,112 cartons per acre). The low-input IPM program yielded an average of 2,751 marketable cartons per hectare (1,105 cartons per acre). Based on Free on Board (F.O.B.) market prices at the time of harvest. The net loss for the grower standard was $-3,415 per hectare ($-1,382 per acre), and the net loss for the low-input IPM program was $-2,472 per hectare ($-1,000 per acre). The net loss is attributable to the grower harvesting the field to meet a preexisting contractual commitment. Had the harvest been timed to when market prices were more favorable, the grower could have realized a net profit, with the low-input IPM generating a greater net profit.

In addition to the more favorable economic results (i.e., lower net loss), the low-input IPM program has benefits for the environment. In the second year of this cooperative research project, the grower has adopted many aspects of the low-input program. The insecticides selected for use by the grower were the same as those proposed for use in the low-input IPM program. All are formulated without volatile solvents. Therefore this low-input approach would not contribute substantially to air pollution from volatile emissions.

In both years of this project we have demonstrated that further reductions in pesticide use can be made in the production of high value, low-damage-threshold vegetable crops such as celery. This reduction in pesticide use can be made without sacrificing yield, quality or net profit. The progressive pest management policy of the grower made this validation test of the low-input IPM program conservative. Therefore, many growers could show greater economic benefits from adoption of such low-input programs.

Introduction:

We proposed to implement a low-pesticide-input integrated pest management (low-input IPM) system for celery, and compare its performance with conventional high-pesticide-input management systems. This proposal directly relates to the DPR program's goals of making agriculture economically viable, environmentally sound, and socially acceptable. Because of low damage thresholds, celery is among the most intensively managed vegetable crops and therefore is a model system for development of low-input IPM programs. Successful development of low-input IPM programs in such an intensively managed crop will facilitate the acceptance of similar programs for other vegetable crops.

The second year of this two-year project was completed on schedule. This study has been conducted on a commercial scale in collaboration with a celery producer, in Ventura County. The field site for the second year of the study was the Gene Jackson Farms' Patterson Ranch, Ventura, California. The success of the first year of the study encouraged the commercial cooperator to adopt a similar low-input IPM program for the second year of the study. Therefore our objectives for the second year of the study were to generate a partial budget economic analysis comparing the monetary returns (gross costs, net gain/profit) accruing from the use of current conventional insecticide practices and the low-input program on a standard commercial variety of celery and determine if further reductions in insecticide use could be made; to estimate the potential for air pollution from solvent emissions from insecticide applications; to determine the impact of different adjuvants on the efficacy of a new, widely used insecticide; and to communicate the findings to the vegetable industry and local community.

Material and Methods:

Because of California state law mandating a celery free period, fields in Ventura County could not be planted until August 1998. This fact was taken into account in our schedule, and transplanting of celery into the experimental plots began August 8, 1998. Plantings consisted of field-grown 'G12' celery transplants.

Experimental plots for the first year were staked out and arranged in a randomized complete block design. The two insecticide treatments were the low-input pest management (low-input IPM) treatment and the grower's standard treatment. Based on the results of the first year of the trial, the grower elected to use a program similar to the low input IPM program. Therefore, the major difference between the two treatments was in the decision of when to apply insecticides. In addition to the originally proposed insect pest management program comparison, we included a program to monitor the impact different adjuvants have on the efficacy of spinosad, a novel insecticide which has become widely used in the USA. In this part of the project, there were two treatments. One treatment combined spinosad and an oil-based adjuvant, and the second treatment combined spinosad and a silicone-based adjuvant. The four treatments were laid out in a randomized block design with three blocks and four replicates per block. Each replicate was 0.4 ha (1acre) in size. No untreated control was incorporated into the design because the grower could not be expected to tolerate the probable economic loss.

Determination of the need for insecticide applications in the low-input IPM treatment was based on insect counts. Because of the constant sprinkler irrigation of celery following transplantation, arthropod sampling was not possible until August 24, 1998. Evaluations of lepidopteran populations, based on counts of 20 plants per replicate, were conducted on a weekly basis since that date. For lepidopterous pests, treatments in the low-input IPM were applied when average densities exceeded 2 larvae per 20 plants. *Liriomyza* spp. populations were also evaluated by weekly counts of leafminer larvae in foliage of 20 plants per replicate, and later by counting larvae and puparia collected in 4 (10.2 by 20.4-cm) trays per replicate. *Liriomyza* spp. populations exceeding 10 per replicate (early season) or per tray (late season), in the low-input IPM plots were considered above threshold. The other three treatments received insecticide applications as determined by the grower.

The low-input IPM program relied on biological control agents, and environmentally safe bio-rational insecticides applied only "as needed" in a rotational strategy to delay pesticide resistance. Resistance management is a paramount concern, given the broad resistance to synthetic insecticides of two key celery pests, *Spodoptera exigua* and *Liriomyza trifolii*, and the increasing pest status of *L. huidobrensis*.

Insect pest pressure was high enough to warrant treatment in both the grower standard and low-input IPM plots. The insecticides used and the number of respective applications in the chemical standard treatment was at the discretion of the grower. The grower standard plots received seven separate applications of insecticides whereas the low-input IPM treatments received six separate insecticide applications.

In the low-input IPM treatment, we rotated among commercial formulations of *Bacillus thuringiensis* (up to 1.67 kg [AI]/ha, Xentari, Abbott, Chicago, IL), tebufenozide (RH-5992 [Confirm], Rohm & Haas, Philadelphia, PA, at 1.12 kg [AI]/ha) and spinosad (0.06 kg [AI]/ha, Success, Dow Elanco, Indianapolis, IN) to control lepidopteran populations above the threshold values. The insecticides used to control lepidopterous pests in the low-input IPM program were selected for their minimal impact on *Liriomyza* spp. parasitoids. Populations of *Liriomyza* spp. did not exceed threshold values in the low-input IPM plots. The grower standard used one insecticide application specifically to control leafminers. However, the grower used spinosad, in part, because of its activity against leafminers.

Two applications of oxamyl (1.07 and 1.60 kg [AI]/ha, Vydate L, DuPont, Wilmington, DE) and one of acephate (1.10 kg [AI]/ha, Orthene 75S, Valent USA, Walnut Creek, CA) were made to control aphid and *Lygus* plant bug infestations in the low-input plots. The other three treatments received two applications of oxamyl and two of acephate to control aphids and *Lygus* plant bugs. These treatments were necessary because of a lack of biological control or biorational insecticides available to control these pests. The commercial nature of the project necessitated that the grower have ultimate discretion in applying pesticides to the field.

Fields were harvested on October 22 and 26th by commercial harvest crews employed by Gene Jackson Farms. Harvest crews were unaware of treatment differences among plots. The numbers of cartons in each size class harvested from each replicate were recorded.

Results and Discussion:

Objective 1: To generate a partial budget economic analysis comparing the monetary returns (gross costs, net gain/profit) accruing from the use of current conventional insecticide practices and the low-input program on a standard commercial variety of celery.

For the economic analyses, all non-pesticide costs were derived from industry-wide standards (see Trumble, J. T. et al. 1997, J. Econ. Entomol. 90: 139-146). Harvest and marketing costs were also determined in this manner. All pesticide costs (materials and labor) were derived from costs supplied by commercial application firms for treating large acreages of celery. Market prices used for analyses are the free on board (F.O.B.) shipping point prices for the South District of California on the date nearest harvest (USDA Market News Service).

The low-input program had one fewer insecticide applications (six versus seven trips through the field) than the grower standard program. Although the applications for aphid and *Lygus* plant bug control were outside of the scope of the low-input program, the costs were still charged to the low-input program. Nevertheless, the low-input program still used 27% fewer insecticides than the grower standard program with no negative impact on yield or net profit. The reduction in insecticide use resulted in savings of $208.70 per hectare in insecticide costs.

Despite the differences in insecticide applications, there were no statistically significant differences in the yield (Figure 1) or net profit per hectare for the grower standard and low input IPM programs (Figure 2). The grower standard practice had an average yield of 2,731 marketable cartons per hectare (1,105 cartons per acre). The low-input IPM program yielded an average of 2,770 marketable cartons per hectare (1,121 cartons per acre).

Based on Free on Board (F.O.B.) market prices at the time of harvest, yields from all treatments would have resulted in a net loss for the grower. The net profit for the grower standard was $-3,415 per hectare ($-1,382 per acre. The net profit for the low-input IPM program ($-2,472 per hectare, $-1,000 per acre) was almost $1000 per hectare greater than the net profit for the grower standard program. The net loss for the second year of the study resulted from the grower harvesting the field in order to meet a preexisting contract obligation. Had the grower been able to harvest the crop when market prices were more favorable, as in the first year of the study, the grower could have realized a net profit, with the low-input IPM generating a greater net profit.

Objective 2: To estimate the potential for air pollution from solvent emissions from insecticide applications.

The insecticides selected for use in the low-input IPM and grower standard program are formulated without volatile solvents. Therefore these approaches would not contribute substantially to air pollution. Excluding the applications to treat aphid and *Lygus* plant bug infestations, these IPM programs would have resulted in no solvents being released. Given that the average solvent emissions from many current pest management programs can reach 12 liters per hectare per crop, the potential benefits of the low-input IPM program that eliminates emissions could be substantial.

Objective 3: To determine the impact of different spray adjutants on the efficacy of spinosad, a new, widely used insecticide. Spinosad has rapidly become one of the most widely used insecticides for control of lepidopteran and leafminer pests. Therefore we were interested in determining if different adjuvants have an impact on the efficacy of spinosad in an IPM program. In this part of the project, we compared a petroleum-based nonionic spray (Agri-dex, Helena Chemical, Memphis, TN) and an organosilicone-based adjuvant (Silwet L-77 Surfactant, Helena Chemical, Memphis, TN). The silicone-based material enhances penetration of materials into the plant tissue. Therefore, it may increase the activity of spinosad against leafminers. Four applications of spinosad were made to these plots. The grower made one late season aerial application of tebufenozide across all plots. Although the silicone-based surfactant may enhance penetration of spinosad, the two treatments did not differ significantly in terms of yield (Fig. 1) or net profit (Fig. 2). The use of spinosad to control lepidopteran and leafminer pests resulted in comparable yields to the IPM programs. Although the use of spinosad provided satisfactory control, we do not recommend its exclusive use because of the likelihood of resistance development.

Objective 4: To communicate information to the celery industry and the local communities via field days at the research sites, and via the California Celery Research Advisory Board and presentations sponsored by the University of California Extension Service.

Results for the first year of this two-year study have been presented at meetings and in publications accessible to the vegetable producer industry. Presentations have been made at the "Celery IPM Innovator Workshop" that was held on November 6, 1997, in Ventura, and was cosponsored by the California Department of Pesticide Regulation, the California Celery Research Advisory Board and the University of California. The results have also been presented to the California Celery Research Advisory Board and other industry related meetings. The first year results have also been presented at the Annual Meeting of the Pacific Branch of the Entomological Society of America. Articles describing the project have been published in *Vegetable*, November/December 1997, pp. 4-7, and *Agribusiness Fieldman*, November/December 1997, pp.1-4. In addition, a manuscript has been submitted to Agriculture Ecosystems & Environment, and another manuscript for California Agriculture is in preparation.

Preliminary results of the second year of the study have been presented to the California Celery Research Advisory Board. Final results have been presented at other vegetable industry meetings.

Summary and Conclusions:

Potential Benefits: In the first year of this project we demonstrated that such a low-input IPM program is economically viable. This point has been borne out by the commercial collaborator adopting a similar program for the second year of the study. Our results for the second year indicate that through adequate sampling to determine the appropriate need for pesticide applications, further significant reductions in pesticide use can be made by the vegetable industry as a whole. Additional progress in successfully reducing pesticide use could be made by developing similar low-input programs for the control of fungal pathogens. We would encourage the development of monitoring programs similar to the one for *Septoria* late blight for other fungal pathogens. Refinement of such low-input programs for insect and fungal pests will produce successful, comprehensive intelligent plant management programs.

Farmer Adoption: Based on the first year's results, the grower has relied on the same materials used in the low-input IPM program for production. This strategy reflects a significant change that we expect will be adopted by other growers. By collaborating with growers, the benefits of low-input IPM practices can be effectively demonstrated.

Producer Involvement: This study was conducted on large-scale farm plots in collaboration with a commercial celery producer in Ventura County, CA. We selected celery as a model agroecosystem for the development of a low input IPM program for the vegetable industry. Because of low damage thresholds, celery is one of the most intensively managed vegetable crops in California. Successful development of low input IPM in such an intensively managed, high value crop system will facilitate the acceptance of similar low input IPM programs for other vegetable crops in California and nationally. The grower participated in the project by adapting the pest management programs to the constraints of large-scale production agriculture. Therefore, we are able to present other growers with a program that has been tested under "real world" conditions.

The demonstration of clear economic benefits of such low-input IPM strategies to producers is the most effective means to accelerate the adoption of such programs and create a demand for development of additional low-input IPM for other agroecosystems. Therefore, accurate economic information on the benefits of proposed IPM strategies is needed by producers. Creation of partial budgets using accurate economic information provided by growers can generate persuasive data on net profits resulting from specific control strategies. Thus, implementation can occur rapidly once the barrier of 'perceived risks' is eliminated.

Publications Produced:

Articles describing the project have been published in *Vegetable*, November/December 1997, pp. 4-7, and *Agribusiness Fieldman*, November/December 1997, pp.1-4. In addition, a manuscript has been submitted to Agriculture Ecosystems & Environment, and another manuscript for California Agriculture is in preparation.

Appendices

Fig. 1
Fig. 2

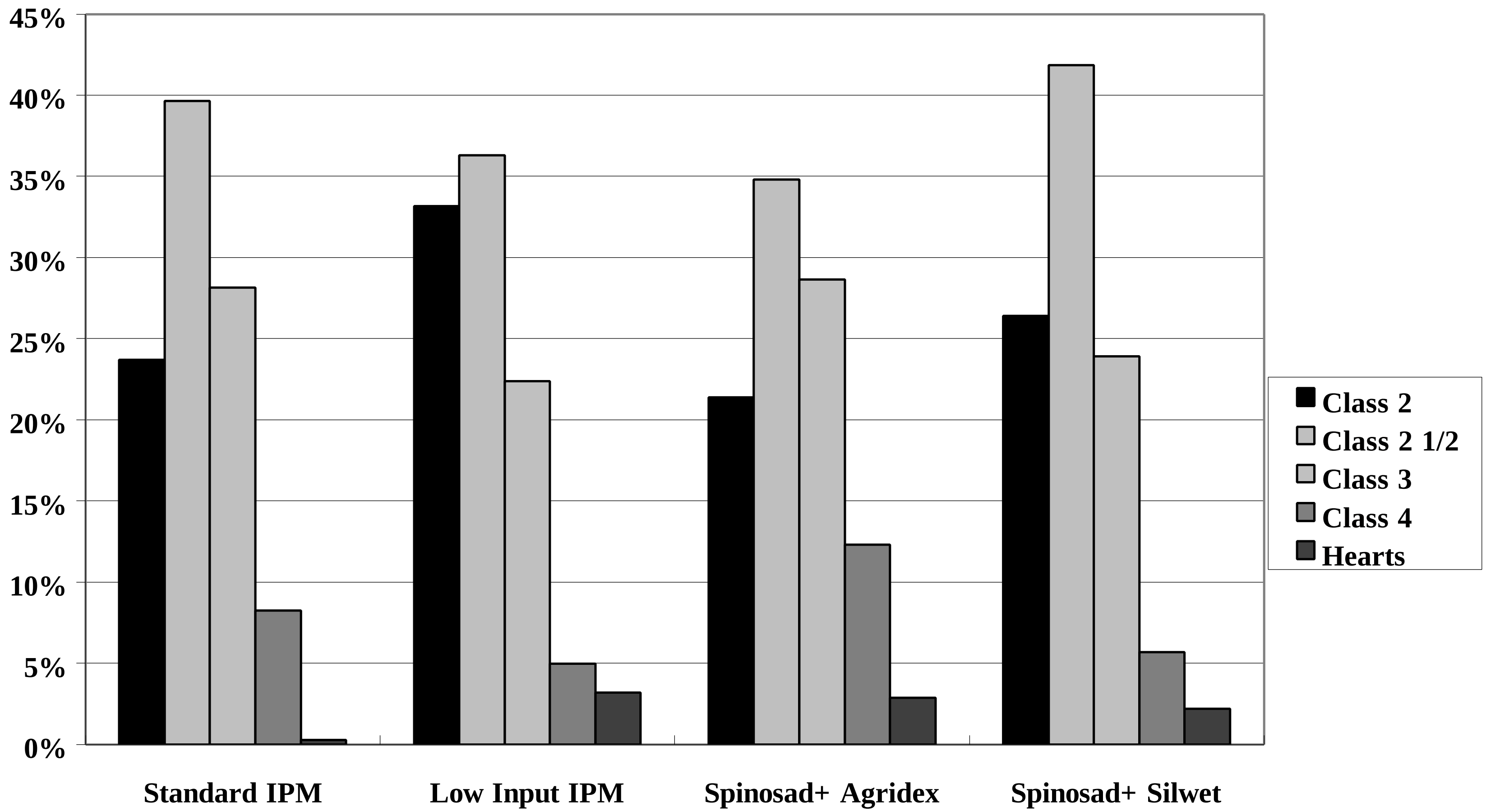

Figure 1. Proportion of cartons in each size class for celery harvested October 22 and 26, 1998 at Ventura commercial fields.

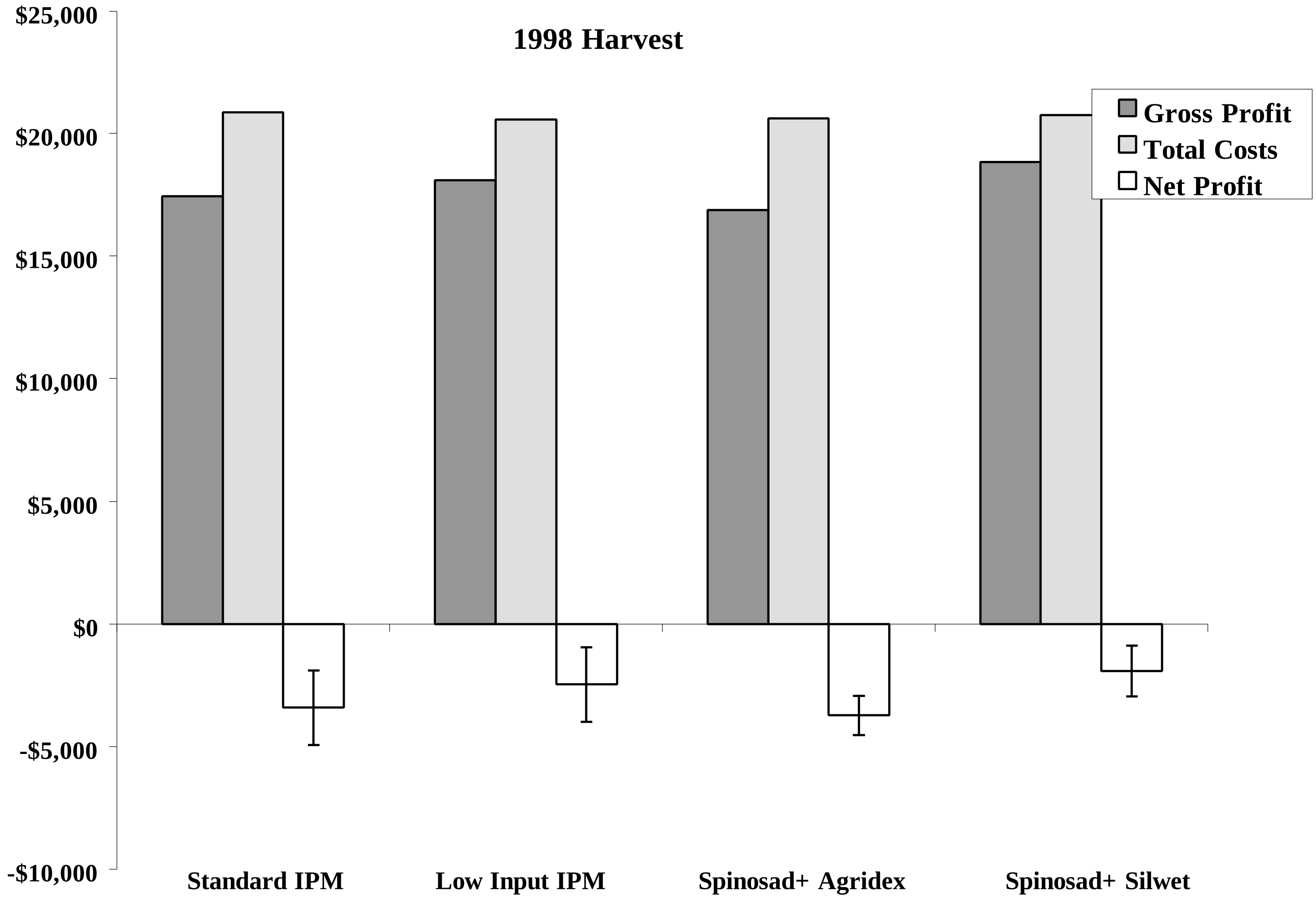

Figure 2. Economic analysis for celery harvest on October 22 and 26, 1998 at Ventura, CA. Total Costs include all production, harvest and marketing expenses. Gross profits are derived from the Free on Board (F.O.B.) prices for each size class of celery. Data are given as means ± SEM, and have been scaled to a hectare basis.